# ENGLISH TRANSLATION OF INTERNATIONAL APPLICATION AS FILED

DESCRIPTION

# OPTICAL MATERIAL, OPTICAL ELECTRONIC COMPONENT AND OPTICAL ELECTRONIC DEVICE

## Technical Field

[0001]

The present invention relates to an optical material, an optical electronic component and an optical electronic device, in particular, an optical material of which amount of birefringence is reduced, an optical electronic component therewith and an optical electronic device therewith.

## Background Art

[0002]

As optical materials for an optical system, glass, plastics, synthesized quartz, calcium fluoride and so on are known.

The glass and plastics are low in the refractive index. For instance, a lens that uses glass has the refractive index of substantially 1.5 (for instance, patent literature 1). When lenses having the same focal distance are tried to manufacture, for the glass, a curvature radius of the lens has to be made smaller. That is, when the material is used, a thickness of the

lens becomes thicker; accordingly, miniaturization and thinning are difficult.

Furthermore, in the optical glasses, materials refractive indexes of which are 1.7 to 2.0 as well have been developed. However, there is a problem in that since the larger the refractive index is, the stronger the coloring is, the light transmittance in a short wavelength region (corresponding to a wavelength from blue to green) in the visible light region tends to be deteriorated.

On the other hand, as to the plastics lens, a complicated shape can be cheaply and readily molded. However, there is a problem in that, since a volume thereof largely varies under the influence of the environmental variation such as temperature and humidity, the refractive index tends to vary to result in causing variation in the focal distance (for instance, non-patent literature 1).

[0003]

Separately from the foregoing materials, as an optical material for optical elements for wavelength conversion, optical diffraction, phase conjugate mirror and so on, single crystals such as lithium niobate and lithium tantalate are known. The optical materials, having the refractive index of 2.0 or more, have possibility of realizing miniaturization and thinning.

However, the single crystals, being a uniaxial crystal, have different refractive indexes for ordinary light and extraordinary light; accordingly, there is a problem in that the birefringence is caused and the doubling results. As a result, the single crystals could not be used in a lens and optical system.

[0004]

There is a proposal of an optical pickup lens for magnetic optical disks, DVDs (Digital Versatile Disk) and so on, in which lithium tantalate that generates the birefringence is used (for instance, patent literature 2). However, to a crystal optical axis of a single crystal, a light incidence axis (light incidence direction) has to be set at an angle of 0° or more (in particular, a crystal optical axis substantially coincides with a light incidence axis (within ± 1°) or substantially 45° (allowable within ± 1°)). Furthermore, it is necessary that laser light that can generate only a very mono-dispersed wavelength is used and a target axis of the lens and an optical axis of the crystal are precisely coincided. Accordingly, when, like in a general image pickup device, to the optical axis of the single crystal, natural light (aggregate of lights having various wavelengths) comes in from all directions (angles), the proposal cannot be applied.

[0005]

Patent literature 1: JP No. 2859621

Patent literature 2: JP-A No. 11-312331

Non-patent literature 1: S. Nagata, ZUKAI RENDU GA WAKARU HON, pp 56-59, (January 20, 2003), First edition, Third printing (NIPPON JITSUGYOU SHUPPAN SHA).

Disclosure of Invention

Problems that the Invention is to Solve

[0006]

That is, lithium tantalate is a material that has the refractive index of 2.0 or more and shows high light transmittance in the visible light region. However, since the birefringence thereof is substantially 0.006, to light incident from various directions, images are duplicated. Accordingly, it has not been used as a lens and optical material.

[0007]

Accordingly, a primary object of the invention is to provide a high refractive index optical material that is not affected by an environmental variation and high in the visible light transmittance and has the birefringence within ± 0.0005, and to provide an optical electronic component therewith and an optical electronic device therewith.

Means for Solving the Problem

[0008]

An invention according to claim 1 is an optical material characterized in that in lithium tantalate a molar composition ratio ($Li_2O/Ta_2O_5$) of lithium oxide and tantalum oxide in the lithium tantalate is 0.975 or more and 0.982 or less.

An invention according to claim 2 is an optical electronic component characterized in that the optical electronic component is formed with the optical material described in claim 1.

An invention according to claim 3 is an optical electronic device characterized in that the optical electronic device contains the optical electronic component formed with the optical material described in claim 1.

Advantage of the Invention

[0009]

According to the invention, even with lithium tantalate that has high refractive index and visible transmittance the birefringence can be confined within a range of $\pm$ 0.0005. Thereby, when the lithium tantalate is used as a lens, the same focal distance can be obtained with a larger curvature radius. That is, the lens can be thinned.

[0010]

The above objects of the invention, other objects, features and advantages will be more clarified from following best modes for carrying out the invention.

Brief Description of the Drawings

[0011]

Fig. 1 is a diagram showing a calibration curve between the Curie temperature and a molar composition ratio.

Fig. 2 is a diagram showing a relationship between the refractive index and a molar composition ratio.

Fig. 3 is a diagram showing a relationship between the respective wavelengths and linear transmittances.

Fig. 4 is a sectional view of a planoconvex lens due to an optical material according to the invention.

Fig. 5 is a sectional view of a planoconvex lens due to glass.

Fig. 6 is a sectional view of a relay lens system made of convex lenses.

Fig. 7 is a sectional view of a relay lens system made of a convex lens and columnar lenses.

Reference Numerals

[0012]

1: Relay lens

2: Convex lens

3: Rod relay lens

4: Columnar lens

Best Mode for Carrying Out the Invention

[0013]

It was found that when a single crystal of lithium tantalate was grown, in the case where a crystal was grown under a particular ratio of lithium oxide and tantalum oxide, the birefringence was reduced, and thereby the invention came to completion.

[0014]

The birefringence means a difference of refractive indexes of ordinary light and extraordinary light. Since when the difference is large, an image is observed duplicated, one that is large in the birefringence is difficult to be used as an ordinary lens.

On the other hand, when the birefringence is within $\pm 0.0005$, since it is within error of the refractive index of ordinary light, an image is not observed duplicated.

[0015]

In lithium tantalate that is an oxide single crystal, a

molar composition ratio ($Li_2O/Ta_2O_5$) of lithium oxide and tantalum oxide in the lithium tantalate is 0.975 or more and 0.982 or less.

When the molar composition ratio is less than 0.975 or exceeds 0.982, in some cases, desired birefringence cannot be obtained.

[0016]

When measuring the molar composition ratio of lithium oxide and tantalum oxide, it is usually difficult to quantitatively measure the molar composition ratio at the precision of 0.01 according to a composition analysis. Accordingly, it is desirable to measure the molar composition ratio with the Curie temperature that is a physicality value sensitive to the molar composition ratio of lithium oxide and tantalum oxide as an index.

However, depending on a measurement method of the Curie temperature, the composition may differ. Accordingly, the molar composition ratio in the invention means a ratio obtained according to a measurement method described below.

[0017]

The Curie temperature is measured by use of a differential thermal analysis method.

Measurement conditions are as follows.

• Measurement temperature range: from room temperature to 800°C.

• Temperature rise speed: 20°C/min.

• Gas: air 100 ml/min.

• Measurement vessel: platinum cell.

• Reference sample: platinum.

• Sample amount: 130 mg.

• Temperature calibration: With indium (melting temperature; 156.6°C), tin (melting temperature; 231.97°C), zinc (melting temperature; 419.6°C), aluminum (melting temperature; 660.4°C) and gold (melting temperature; 1064.4°C), from standard melting temperatures and measurement values of melting temperatures, a calibration equation is prepared.

• Standard deviation values as measured temperatures are within 1.0°C.

• A detection amount of $\Delta$(Li/Ta) per 1°C variation of the Curie temperature is $6 \times 10^{-5}$.

A calibration curve between the Curie temperature and a molar composition ratio is shown in Fig. 1.

[0018]

Lithium tantalate may contain at least one element of magnesium, zinc and scandium.

When an optical material made of an oxide single crystal

is irradiated with a light source (xenon or halogen lamp) for a long time, the coloring due to color centers may be caused. In order to inhibit this from occurring, the above elements can be added. This is because the oxides do not substantially show the absorption under the light source.

Furthermore, an addition amount thereof is 0.5 mole percent or more and 10 mole percent or less. The reason why the addition amount is set at 0.5 mole percent or more is because, when it is less than 0.5 mole percent, an advantage obtained by the addition thereof cannot be sufficiently obtained. The reason why it is set at 10 mole percent or less is due to the solid solubility limit.

[0019]

As the optical electronic components that are formed of the optical material, for instance, a lens, a light-pickup lens, a prism, an integrator lens, a polygon mirror and so on can be cited.

[0020]

Furthermore, as the optical electronic devices that are formed of the optical electronic components, for instance, an endoscope, a magneto optical disk, a DVD, a liquid crystal projector, a laser printer, a handy scanner, a digital camera and so on can be cited.

Examples

[0021]

In what follows, more specific examples of the invention will be described. However, the invention is not restricted to the examples.

[0022]

(Example 1)

Commercially available raw material powders of 99.99% purity $Li_2CO_3$ and $Ta_2O_5$ were used. The raw material powders were weighed at a molar ratio of $Li_2CO_3$: $Ta_2O_5$ = 0.55: 0.45 so as to be 6500 g in total and put into a Teflon (registered trade mark) vessel, followed by applying dry mixing. After mixing, the mixture was calcined in air at 1300°C for 8 hrs and thereby a raw material was prepared. The calcined raw material was filled in a soft urethane rubber mold and a molded body was prepared under static pressure of $1.96 \times 10^8$Pa.

[0023]

An Ir (iridium) crucible having an outer form of 140 mm, a height of 100 mm and a thickness of 2.0 mm and an Ir cylindrical tube having an outer form of 100 mm, a height of 110 mm and a thickness of 1.0 mm were prepared. The cylindrical tube was inserted so as to coincide with a central axis of the crucible.

Inside of the combined crucible (hereinafter, referred to a "double crucible"), the molded body was filled, followed by heating the crucible with high frequency induction heating, and thereby a molten liquid was prepared. After a temperature of the molten liquid was stabilized at a predetermined temperature, with a lithium tantalate single crystal that is cut so that a longer direction may be in parallel with an [010] axis as a seed crystal, according to a double crucible method (JP-A-13-287999), a crystal was grown.

[0024]

A growing crystal was grown from immediately after the start of the single crystal growth by use of a diameter automatic control system so that a diameter of a straight body portion may be 50 mm.

A molar fraction $Li_2O_3/(Li_2O_3 + Ta_2O_5)$ of the raw material molten liquid was maintained in the range of 54.5 to 55.5 mole percent. With a double-structured crucible, a lithium tantalate single crystal having a target composition was pulled up from an inner crucible. While sequentially measuring a weight of a pulling-up single crystal, a weight per unit time (weight growth speed) was obtained. At the weight growth speed, a raw material having the same composition as the growing single crystal, specifically, a composition where a molar fraction of

$Li_2O_3/Ta_2O_5$ is controlled in the range of 0.975 or more and 0.982 or less was continuously put in between the outer crucible and the inner crucible to control the crystal composition precisely, and thereby a single crystal of which birefringence is within a target range was grown.

While pulling up a seed crystal at a constant speed for a predetermined time, a molten raw material was solidified. Thereafter, the single crystal was elevated to a predetermined position and cooled over 20 hrs.

[0025]

The obtained single crystal was sandwiched with platinum plates facing in an [001] axis direction of the single crystal and disposed in a resistance heating furnace. This was heated up to 750°C and maintained there sufficiently. Thereafter, while with the platinum plates as electrodes electricity was flowing at a current density of DC 0.5 mA/cm$^2$, the single crystal was gradually cooled at a speed of 20°C/h to room temperature.

[0026]

The Curie temperature of the obtained single crystal was obtained by means of the foregoing differential thermal analysis method (TG-DTA (trade name), manufactured by Seiko Instrument) under the foregoing measurement conditions and found to be 661.5°C. When the value was referenced to the calibration curve

to obtain the molar composition ratio of lithium oxide and tantalum oxide, the molar composition ratio of 0.980 was found.

[0027]

The single crystal was mechanically cut and a wafer (Y-cut wafer) having surfaces vertical to a b axis was prepared. Both surfaces of the wafer were physically mirror polished with a polishing agent to a thickness of 0.5 mm. Thus, a sample according to the invention was obtained.

The sample was measured of the linear transmittance and the refractive index.

[0028]

The refractive index was measured of both surfaces of the wafer at a wavelength of 632.8 nm by use of a prism coupler type refractive index measurement unit (manufactured by Metricon Co., Ltd.).

The measurement accuracy of the unit is ± 0.0001 and the measurement resolution power is ± 0.00008.

As a result, the refractive index of ordinary light, $n_o$, was found to be 2.1770 ± 0.0002. Since the refractive index of extraordinary light, $n_e$, was within the resolution power of the measuring unit to $n_o$, that is, coincided with $n_o$ at $\Delta n = |n_o - n_e| \leq 0.0002$, the single crystal was found to be an optically isotropic material.

Results are shown in Fig. 2.

[0029]

The linear transmittance was measured with a spectrophotometer (trade name: UV-200S, manufactured by Shimadzu Corporation) in a measurement wavelength range of 200 nm to 1700 nm. The linear transmittance was found that an absorption edge was at substantially 260 nm and in a wavelength range of 300 nm or more the absorption coefficient was 0.5 $cm^{-1}$.

Results are shown in Fig. 3.

[0030]

From the foregoing sample, a disk sample having a diameter of 20 mm was cut out and the sample was processed to a planoconvex lens having a front curvature of 50 mm and a rear curvature of infinity. The focal distance thereof was measured and found to be 42 mm (Fig. 4).

For comparison, a planoconvex lens having a focal distance of 42 mm was prepared from an optical glass material BK-7 (borosilicate crown glass, n = 1.51, manufactured by Shot Co., Ltd) and found to have a front curvature of 23 mm (Fig. 5).

From the above, the inventive optical material can be thinned in comparison with glass.

[0031]

(Example 2)

Of a relay lens 1 such as shown in Fig. 6, which is made of only convex lenses 2 that are made of a material according to the invention (gaps between the respective lenses are made of air), a rod lens relay 3 where a convex lens 2 and columnar lenses 4 are arranged as shown in Fig. 7 and made of glass (BK-7, n = 1.51), and a rod lens relay 3 where a convex lens 2 and columnar lenses 4 are arranged as shown in Fig. 7 and are made of a material according to the invention, the NAs and brightness of the respective optical systems were compared. The NA means an effective diameter (aperture diameter) through which an image enters. Furthermore, arrow marks in the drawings show a substance whose image is inverted owing to an imaging effect.

In Table 1, based on the relay lens 1 constituted of only the convex lenses 2 shown in Fig. 6, relative numerical values of the rod lens relays 3 made of glass and the material according to the invention are shown.

[0032]

[Table 1]

| | Optical path length | NA | Brightness |
|---|---|---|---|
| Relay lens made of only convex lenses | 1.0 | 1.0 | 1.0 |
| Glass (BK-7) | 0.6 | 1.5 | 2.3 |
| Inventive material | 0.5 | 2.2 | 4.8 |

[0033]

As shown in Table 1, when the inventive material is used as a material of the columnar lens 4, in comparison with an ordinary relay lens 1 where the convex lenses 2 alone are used, an optical path length L can be shortened and the NA can be increased; accordingly, the brightness was found increased in proportion to the refractive index. Thereby, since an effective diameter of the lens can be made smaller, in an endoscope for instance, a diameter of the endoscope can be made smaller; accordingly, an endoscope that can be easily operated and alleviate burden on a patient can be provided. Furthermore, since two units of the same optical system can be readily arranged, a stereo optical unit can be constituted and thereby a detailed three-dimensional image can be observed.

Industrial Applicability

[0034]

An optical material according to the invention can be applied to a lens and the lens can be applied to an optical electronic component.